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Advanced High-speed Optically Isolated Digital Data-link for Hostile Environments

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Abstract--A third-generation high-speed optically isolated digital data-link was developed at Lawrence Livermore National Laboratory. It is very reliable despite ground jumps between the transmitter and receiver, and it has link-failure detection circuitry. Although the link design is complex, it is more cost-effective than fiber-optic links for eliminating ground loops or electrical interference.

A standard procedure to prevent external electrical interference or ground noise from coupling into sensitive equipment is to isolate digital data optically(1), (2). One high-speed and highly reliable standard circuit used at Lawrence Livermore National Laboratory (Fig. 1) provides optical isolation between the two chassis, but exposes the grounds and power rails of the transmitter chassis to any coupled-in noise along the cable. Where the cable runs are long and the environment they pass is hostile, this circuit is not sufficiently reliable.

In a slightly more advanced circuit (Fig. 2), both the transmitter and receiver are optically isolated from the cable. This more expensive dual-configuration system dramatically reduces errors during data transmission and still maintains high speed. However, during actual use to control 24 large, high-power (40-kV, 80-A) high-speed (I rise/fall <2 μs) modulators, some disadvantages the dual-configuration system shares with its predecessor were discovered. First, when dual-configuration circuit is powered up, it comes up in random states. Second, when the cable connector between the transmitter and receiver is unplugged, the resulting transients can change the state of the output flip-flop and leave it in the wrong state. This second problem is serious if the digital-data link is used to activate pulsed modulators or similar duty-factor sensitive-equipment. Third, the status of this communication link only becomes apparent when it is being used. Component failure and failure to connect the cable are not easy to detect. Fourth, high voltage transients caused by local sparkdowns can temporarily raise the local ground potential with respect to the other end of the cable and result in large currents that often destroy the optical isolators.

To correct all these problems, a third, and more refined, optical isolation circuit was tried (Fig. 3). This circuit provides automatic power-on clearing when the voltage is first turned on by using the resistor-capacitor (RC) circuit (lower righ-hand corner) with the Schmitt triggered buffer. The time constant of the RC circuit is adjusted so the output will be low (active clear) for 50 ms after the power is turned on. If there is a momentary power outage, the Reed relay resets the time-delay circuit by shorting out the capacitor.

The circuit above the power-on-clear prevents the transients, caused by removing a cable, from toggling the output flip-flop into the wrong state. The output flip-flop is needed to prohibit a fast noise spike from coupling into the output. The protection circuit is designed to automatically clear the output flip-flop after both optical isolators show no output for more than 1 ms. In addition, the exclusive-or-gate in this circuit detects the occurrence of simultaneous active-outputs on the optical isolators, a prohibited condition that indicates component failure. At the transmitter end, a similar link incomplete/error indication is provided (see the circuit on the bottom left-hand side of Fig. 3).

The zener diodes in series with the Schottky diodes at the receiver end of the circuit limit the differential voltages induced in the line without affecting the data transmission rate. The four Schottky diodes at the transmitter end clamp any common mode transients by keeping the remote ground and the transmission line close to the same potential. The four, 25-Ω resistors protect the diodes by limiting the transient currents. To prohibit the remote ground from floating above the breakdown potential of either the optical isolators or the isolated power supply, a 1-kV varistor in parallel with a 1-kΩ resistor connects the remote ground to the earth or to the chassis ground.

This third link design is more expensive than the other two, but it has proven reliable and extremely rugged. In cases where fiber-optic links are being considered to eliminate ground loops or reduce electromagnetic-interference problems only, the optically isolated data-link presented here is usually faster and less expensive than many commercial fiber-optic systems.

ACKNOWLEDGMENT

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REFERENCES

(1) Hewlett Packard, High Speed Optically Coupled Isolators, Hewlett Packard, Palo Alto, Calif., HP Application Note 939, 1979, p. 1.

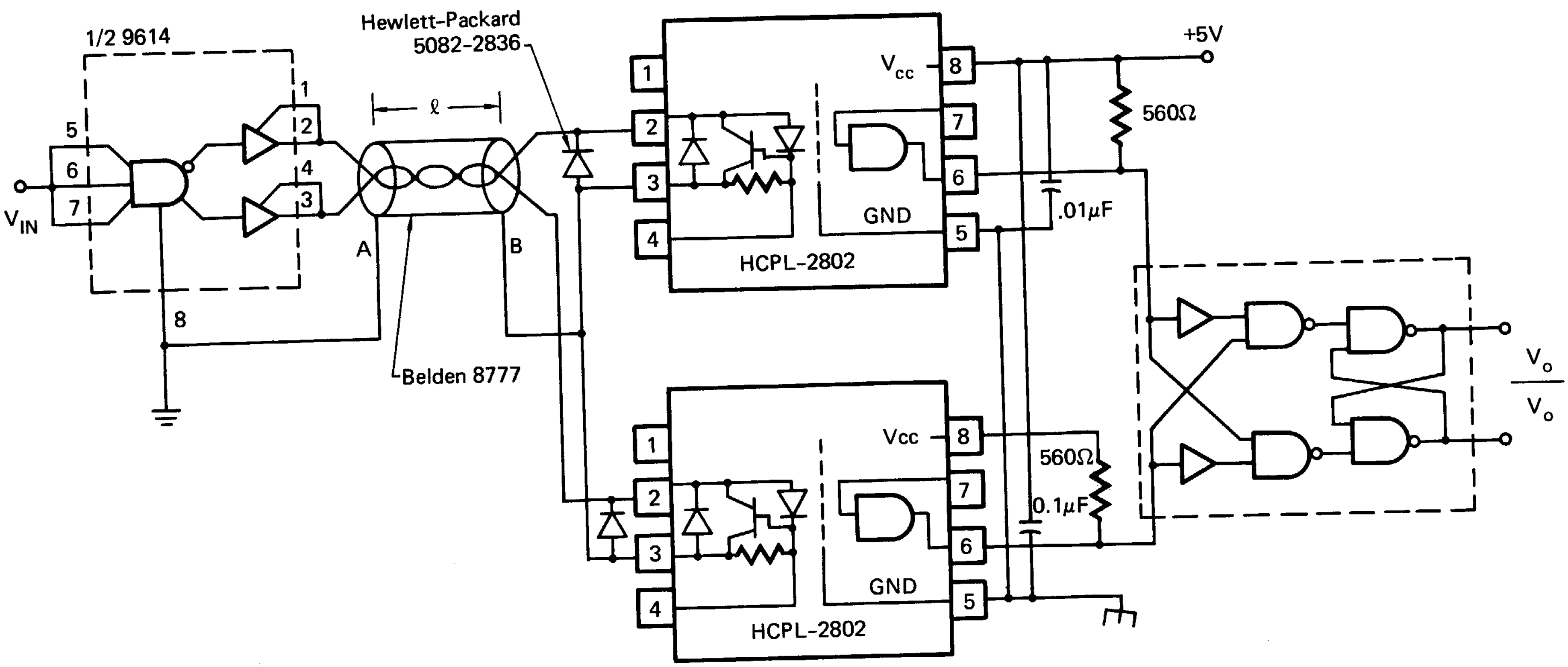
(2) Hewlett Packard, Digital Data Transmission Using Optically Coupled Isolators, Hewlett Packard, Palo Alto, Calif., HP Application Note 947, 1979, p. 1.

Figure Captions

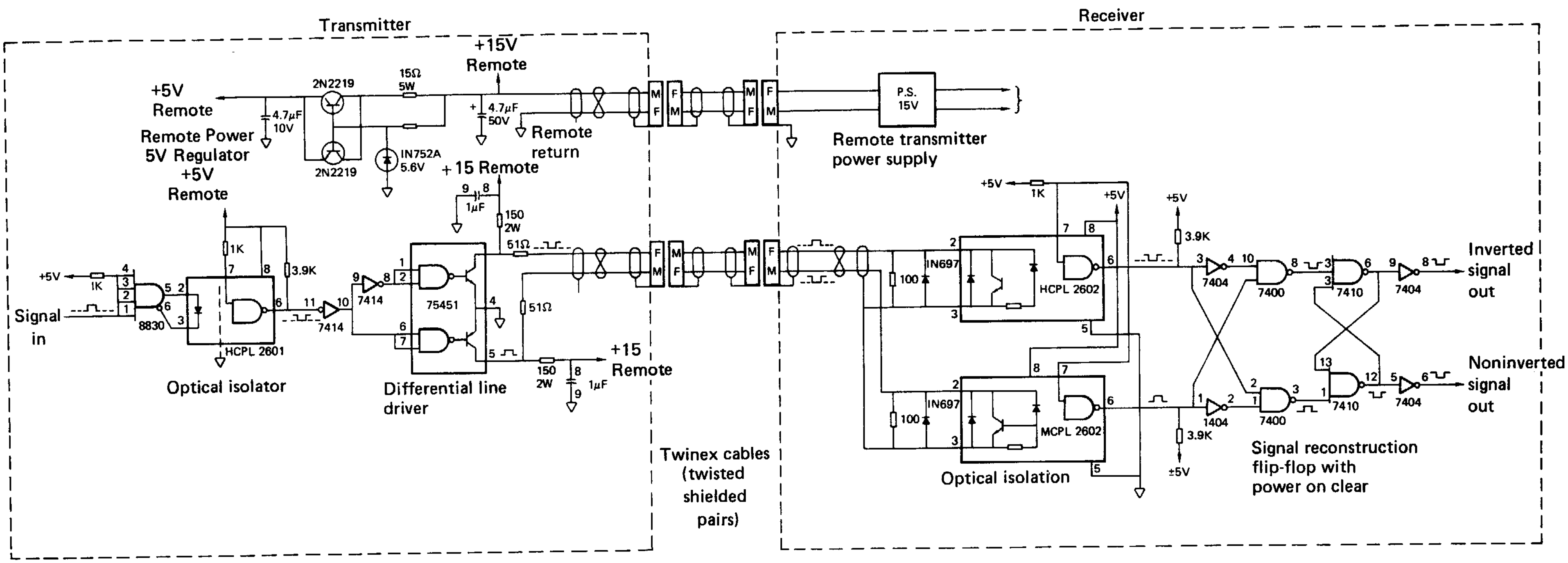
Fig. 1. Circuit of the first optically isolated digital data-link used at Lawrence Livermore National Laboratory. This is a Hewlett Packard system and the diagram is used here with permission from Hewlett Packard, Optoelectronics Division.

Fig. 2. Circuit of a dual, optically isolated digital data-link. This is the second-generation data link developed and used at Lawrence Livermore National Laboratory.

Fig. 3. Circuit of an advanced, optically isolated digital data-link. All diodes are Schottky diodes. This is a third-generation system developed and presently used at Lawrence Livermore National Laboratory.

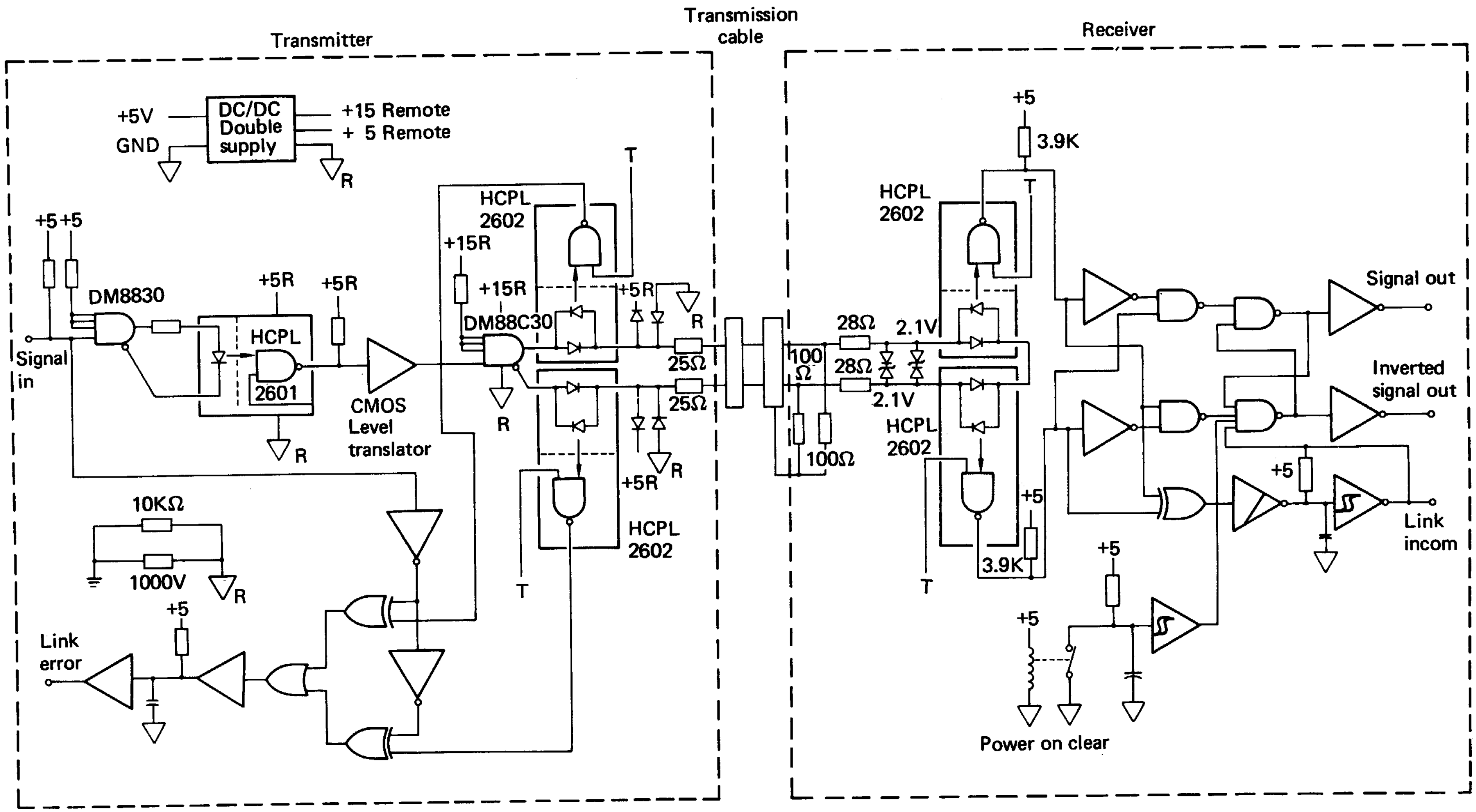

1/2 9614
Hewlett-Packard
5082-2836
Belden 8777
ℓ
A
B
V_IN
+5V
V_cc
Vcc
560Ω
.01µF
0.1µF
GND
HCPL-2802
V_o
V_o

Ross - Fig. 1



Transmitter
Receiver
+5V Remote
Remote Power 5V Regulator
+5V Remote
2N2219
2N2219
15Ω 5W
+15V Remote
4.7μF 10V
4.7μF 50V
IN752A 5.6V
Remote return
+ 15 Remote
P.S. 15V
Remote transmitter power supply
+5V
1K
Signal in
8830
HCPL 2601
Optical isolator
3.9K
7414
7414
75451
Differential line driver
150 2W
51Ω
1μF
+15 Remote
Twinex cables (twisted shielded pairs)
IN697
100
HCPL 2602
MCPL 2602
Optical isolation
3.9K
7404
1404
7400
7410
Signal reconstruction flip-flop with power on clear
Inverted signal out
Noninverted signal out

Ross - Fig. 2


Transmitter
Transmission
cable
Receiver
+5V
GND
DC/DC
Double
supply
+15 Remote
+ 5 Remote
R
T
HCPL
2602
+15R
+15R
+5 +5
DM8830
+5R
+5R
HCPL
2601
Signal
in
CMOS
Level
translator
DM88C30
R
+5R
R
25Ω
25Ω
R
+5R
HCPL
2602
T
10KΩ
1000V
R
+5
Link
error
100
Ω
100Ω
28Ω
28Ω
2.1V
2.1V
+5
3.9K
T
HCPL
2602
HCPL
2602
+5
3.9K
T
Signal out
Inverted
signal out
+5
Link
incom
+5
+5
Power on clear

Ross - Fig. 3